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IT on the Shop Floor - Challenges of the Digitalization of manufacturing companies

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Abstract

A new generation of information technology (IT), promises significant benefits for manufacturing companies in their daily work. However, the companies are rather slow in taking advantage of the opportunities offered by the current wave of digitalization. This paper starts with an overview of emerging sociotechnical trends in manufacturing. We discuss technology as catalyser of this transformation process and its impact on individual and organisational levels. The intense collaboration with six manufacturing companies in a European project allowed us to identify and further specify four digital challenges: 1) Digitally augmented human work, 2) Worker-centric knowledge sharing, 3) Self-learning manufacturing workplaces, and 4) In-situ mobile learning. The four digital challenges illustrate how companies (can) embrace emerging sociotechnical trends in manufacturing and thus contribute to a better understanding of the changing role of IT on the Shop Floor.

Keywords: Digitalization, Smart factories, Shop floor, Industry, Manufacturing, Sociotechnical, Trends, worker-centric, knowledge sharing, in-situ mobile learning

1 Introduction

The ever increasing global competition leads industrial companies to engender organisational changes and drive innovations. A new generation of information technology (IT) can contribute to the transformation of the shop floor: on the one hand by advancing the automation of manufacturing processes (Armbruster et al., 2007; Brettel et al., 2014; Chi, 2013) and on the other hand by putting shop floor workers and their skills more in the focus (Campatelli et al., 2016; Steinhüser et al., 2017).

However, so far, manufacturing companies have been slow in taking advantage of the possibilities offered by the current wave of digitalization (Hessman, 2013). Yet, we know little about the information needs and possible benefits of IT for the manufacturing sector (Daeuble et al., 2015).

Therefore, the goal and main contribution of our study is to identify, describe and explore current challenges that companies are facing due to emerging sociotechnical trends in the manufacturing sector. For this context, we define a digital challenge as the combination of 1) the identification of the problem situation 2) the implementation of a sociotechnical solution to address the problem and 3) the continuous transformation of the existing work practices.

We start this paper by presenting emerging sociotechnical trends that are currently engendering changes in manufacturing. We start by discussing technology as catalyser of this transformation process and then discuss its impact on individuals and the organisation (Chapter 2). In Chapter 3, we explain how the close collaboration with six industrial companies in a European project for more than two years (so far) has allowed us to identify and then further specify four digital challenges. Those are 1) Digitally augmented human work, 2) Worker-centric knowledge sharing, 3) Self-learning manufacturing workplaces, and 4) In-situ mobile learning).

Next, we illustrate each digital challenge with an example of a company from the project. For each case, we describe the problem situation and then the proposed solutions to overcome problems being faced by each that have been implemented or are currently implemented. Thus, drawing on the insights from these companies we demonstrate how the manufacturing industry can leverage challenges they are experiencing. Beyond practical relevance, this conceptualisation of the current situation as “digital challenges” for manufacturing companies helps building the basis for a better theoretical understanding of the changing nature of IT on the Shop Floor.

In Chapter 5, we discuss how to take a step forward by proposing sociotechnical solutions for the workers in response to these digital challenges, to support their work practices and increase job satisfaction.

2 Emerging sociotechnical trends in the manufacturing sector

In the following, we present sociotechnical trends that emerge in the context of manufacturing. In order to identify these trends, we thoroughly reviewed the latest literature, the public media as well scientific publications. We categorize the trends into three pillars, as summarized in Figure 1, and discuss them in the following sections: (1) Technology, which is the basis for this transformation and catalyses the other changes on (2) Individual and (3) Organisational levels.

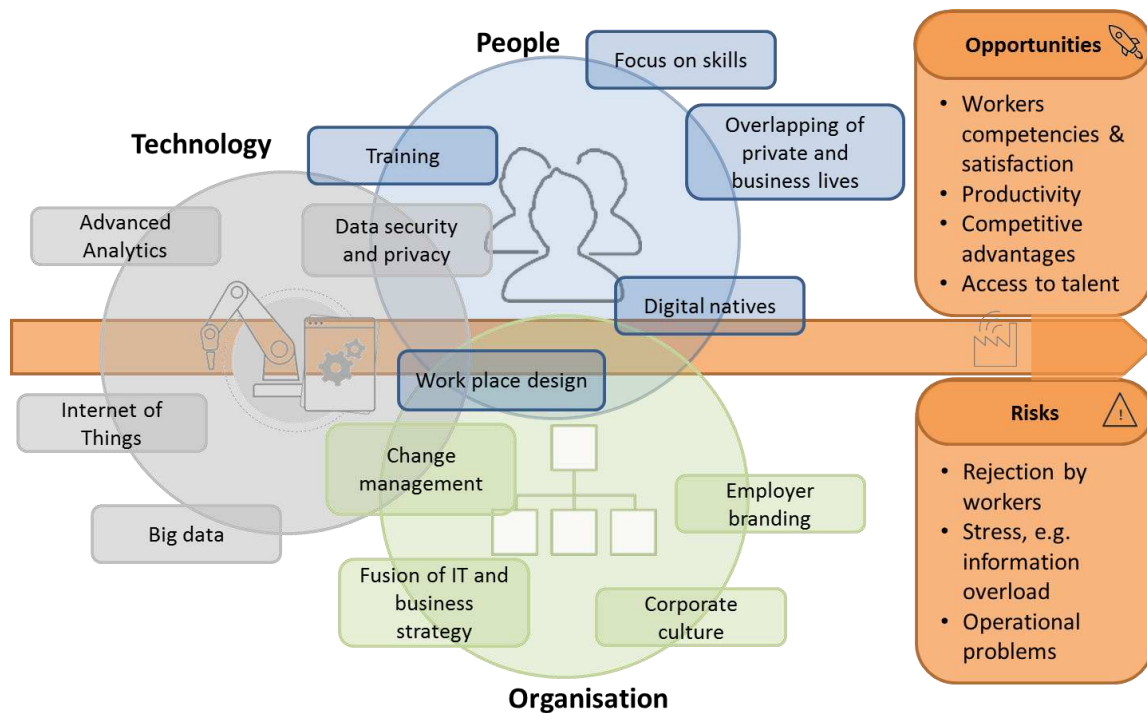


Figure 1: Emerging sociotechnical trends in the manufacturing sector

2.1 Technology

New technological developments can serve as drivers for change on organizational and individual levels (Köffer, 2015). The following recent technological trends have the potential to substantially affect the workers' situation on the shop floor and also the organisation of manufacturing environments.

The web-based linking of machines, sensors, computers, and also humans, is rapidly moving towards the idea of the connected factory (Bono and Pillsbury 2016). The benefits of the so-called "Internet of Things" (IoT) technologies include reduced down time, increased quality and less waste as well as greater visibility of the manufacturing floor. This connectivity enables companies to leverage the value of their plant floor information and promises an increase in productivity, improved utilization of assets, and better decision-making (Bradley, 2015). Whereas recent technical advances in interoperability have resulted in higher maturity of product and process models (Tibaut et al., 2016), companies still face the task of building coherent services when the individual components are technically different and managed by different units.

IoT technologies allow devices to communicate automatically and enable companies to monitor, collect, process, and analyse huge amounts of data, which may lead to more precision and the chance to get deep insights into manufacturing processes. Measuring and monitoring real-time data from across the factory leads to rapidly growing data sets that are increasingly gathered by cheap and numerous sources and often so large or complex that traditional data processing applications are inadequate to deal with. In this context, the term big data was coined. To capture business value and meet the demands of smart manufacturing, companies need to be

able to manage these large data sets and extract meaning out of them (O'Donovan et al., 2015). This large quantity of data leads to new questions and solutions concerning especially the analysis, search, sharing, updating, and visualization.

Advanced analytics in the form of predictive analytics, user behaviour analytics, or certain other methods that extract value from data, are needed to cope with this great amount of data (Lee, 2013; Wambaa et al., 2015). It offers possibilities to make extensive use of analytical tools often capable of providing diverse reporting on any device, anytime. These tools are able to deliver data about companies' productivity and security as well as supporting decisions according to product configurations, service bundles, and pricing options. The utilization of metrics is evolving at a rapid pace and will become even more pervasive in the future (Van Herreweghe et al., 2015). Danson et al. (2016) state that "industrialized analytics" is increasingly influencing business strategy and commanding substantial investment and connecting analytics capabilities is crucial for manufacturing companies.

2.2 Individual Level

As with any new way of working, or even more general - of doing - individuals need to learn and adopt it, get used to it, and, in the best case, benefit from it. Striving towards a smart factory may have an enormous impact on work practices on the shop floor. Employees face changed processes, they need to handle new technologies and accomplish different tasks. As one out of three trends for the future of manufacturing the World Economic Forum, therefore, identified the focus on the workforce's skills (McNelly, 2016). With the spreading and growing importance of technology in the manufacturing sector, the need to be able to acquire new skills to get the work done properly increases. Individuals are not only facing changes of technologies, but, as a consequence, also the increasing complexity.

Providing workers with information where and when it is needed and, more generally speaking, supporting the employees in their daily work promises significant benefits (Daeuble et al., 2015; Mavrikios et al., 2013). As a consequence, shop floor workers are expected to solve occurring problems as fast as possible and to constantly improve their work-related knowledge and skills (Appelbaum, 2013; Ullrich, 2016).

People who were not born into the digital world have learnt to use different kinds of technology at some stage in their adult lives and are likely to experience some difficulties in accepting technology related changes at work. Conversely, the "digital natives" have grown up with diverse IT. The entering of digital natives into the workplace might mark a paradigm shift (Vodanovich et al., 2010). The way people process information fundamentally differs and depends from how and when they grew up. Thinking patterns have changed and it is very likely that even their brains have physically changed (Ng, 2012; Wang et al 2012). It could be shown, that this implies an ease with which digital natives learn to make use of unfamiliar technologies (Ng, 2012; Wang et al., 2013). They need, however, to be provided with the opportunity to use them for meaningful purposes (Huyler et al., 2015). In order to remain competitive, companies need to take this into account.

Another perspective on the same phenomenon is that some employees may be faced with fears about whether digital natives and smart machines will soon take over their jobs (Brynjolfsson

and McAfee, 2011). However, humans with the most diverse skills and competencies as well as with valuable experience have always added value to manufacturing processes and this is likely to continue (Gorecky et al., 2014). There is a variety of possible ways in which people and machines will work alongside each other (McAfee and Brynjolfsson, 2014). Of course, some will build, implement, maintain, and operate upcoming technologies. Others will be in roles that machines can't perform well, such as those involving high levels of experience, intuition, creativity, or empathy (Danson et al., 2016). Therefore, manufacturing companies should not overvalue digital skills at the expense of "traditional" skills. Instead, they are advised to recognize and promote experience and handicraft talent, too. Focusing on all different kinds of skills is a great challenge but it may create advantages for manufacturers, and also positively impact workers' employment and incomes (Daugherty et al., 2016). When facing this challenge appropriately it is important to rethink and develop group specific learning arrangements and individual work place designs (Köffer, 2015). Organizations will need to examine knowledge-intensive processes and determine which tasks can best be performed by machines and which by humans (Gorecky et al., 2014). Early training and supporting employees to prepare for a collaborative future with smart machines is essential (Danson et al., 2016).

2.3 Organisational Level

The exponential growth of data and the convergence of different affordable technologies are transforming organizations. Key infrastructures are underlying considerable changes that play a vital role in securing competitive positions in the manufacturing industry. Anytime retrieval, monitoring and operating of technology infrastructures, even over huge physical distances, enables simultaneous control and coordination of complex technological processes. Consequently, a shift can be observed, away from centrally controlled processes towards decentralized, distributed structures and processes. As a result, today's strategies, value chains and business models will come under increasing pressure (Kagermann, 2015). Companies need to decide whether to react on emergent demands or to proactively contribute to a transition's design or they can choose between an incremental change versus a radical change (Ullrich et al., 2015). In each case an appropriate change management is crucial.

The prevailing view of IT strategy has mostly been that it is a functional-level strategy that must be aligned with a company's business strategy. The business infrastructure has become digital, though, with increased interconnections among products, processes, and services. The arrival of IoT, Cyber-Physical Systems (CPS) and others allows everything to be networked in order to create a smart environment where people and machines communicate with each other naturally (Kagermann, 2015). This has led to fundamentally transforming not only business processes, products and services but also business strategies. Accordingly, the role of IT strategy has to be rethought, from that of an aligned but subordinated functional-level strategy to one that reflects a fusion between IT and business strategy. Key themes to guide this are, the scope, the scale and the speed of digital business strategy, as well as the sources of future value creation and capture in digital business strategy (Bharadwaj et al., 2013).

When addressing a change in strategy, its success strongly depends on a firm's ability to evolve its corporate culture. Thereby, companies are advised not only to take advantage of emerging technologies, but also, critically, to embrace the new business strategies that those technologies

drive. Enterprises must focus on enabling people to accomplish more with technology (Gorecky et al, 2014). They will have to create a new corporate culture that looks at technology as the way to enable people to constantly adapt and learn, continually create new solutions, drive relentless change, and disrupt the status quo. In times where the focus is locked on technology, it is important, in fact, to place people first (Daugherty et al., 2016). Thus, it is the task of managers to promote an organizational climate that supports decentralized and self-responsible use of information assets. For this, many leaders are likely required to develop new skills, resulting in training recommendations for supervisors, who have a prominent position in digital workflows (Köffer, 2015).

The rise of the generation of digital natives, as stated above, brings a new kind of employee not only with different attitudes towards technology but also with different outlooks, aspirations, and expectations regarding their employer, their workplaces, and about how work should be organized (Wang et al., 2013). It appears that preferences are shifting towards aspects such as connectivity, information or entertainment (Hanelt et al., 2015). The push towards new forms of working challenges organizations. On the one hand, it is important to thoroughly plan and execute the change, on the other hand, there is strong competition between manufacturers for new employees. A successful employer branding would create sustainable competitive advantages. With the right engagement strategy, companies can leverage the excitement for technology, teamwork, and digitalization of younger employees to push forward the business (Daugherty et al., 2016).

3 Research Design

This study is a part of the international research project FACTS4WORKERS. The objective of FACTS4WORKERS is to create attractive and intelligent work places in a factory of the future. Therefore, we initially studied how practices on the shop floor can be supported through human-centred IT solutions. A deep understanding of workers' individual practices has been our basis to deliver suggestions (in the form of requirements) for sociotechnical solutions that support smarter work.

Guiding through the process of exploring smart factory solutions, we identified four digital challenges together with our six industrial partners from the manufacturing domain. The identification was done in the constitutional phase of the project by conducting a focus group with all six companies. The intense collaboration with the companies over a span of more than two years allowed us to deepen our understanding and to further explore the four specific digital challenges.

Further field studies at each of the six companies enabled us to collect data from more than 60 interviews, various observations (also documented by more than 100 photos and 20 videos) as well as at least one further focus group at each partner. For further information about first phases of the data collection please refer to (Heinrich & Richter 2015) and (Denner et al. 2015). This has all contributed to describe their individual challenges in more detail.

4 Digital challenges for manufacturing companies

The role of knowledge in manufacturing companies has grown over the last century and innovations and technologies have changed it radically a number of times (Wan et al., 2014). Currently, the focus has drifted towards knowledge-intensive and human-centred manufacturing. Currently and in the future, human workers have an important role in manufacturing environments, as they are capable of complementing modern technology and performing knowledge-intensive work tasks more effectively compared to solely technical approaches. However, this also will require more knowledge management skills from the workers and manufacturing environments.

The data gathered from six companies allowed us to identify four digital challenges: 1) Digitally augmented human work, 2) Worker-centric knowledge sharing, 3) Self-learning manufacturing workplaces, and 4) In-situ mobile learning. These fall into different facets of knowledge management. While for example predictive manufacturing focuses stronger on the technological aspects of knowledge aspiration, human-centred manufacturing rather focuses on the social aspects (cf. figure 2). Beyond identifying the digital challenges we illustrate all of them with a case vignette each – that gives insights into the situation at the industrial partners' production environments.

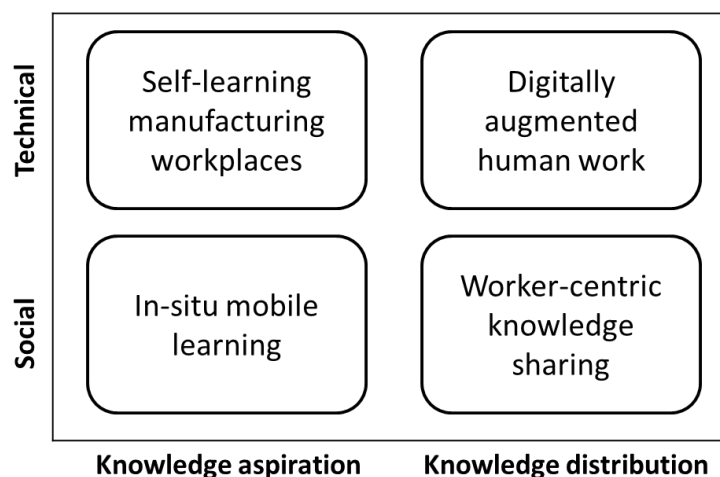


Figure 2: Digital challenges for manufacturing companies

4.1 Digitally augmented human work

Human shop floor workers deal with information that is increasingly more complex and transforming, combined from multiple sources and types. Augmenting human work with digital technologies means to provide them with an immediate and personalized provision of information at the shop-floor-level, which can be interacted (accessed and modified) according to their needs, roles, preferences and constraints (Kagermann 2015). Our research reveals, that one common request of many assembly and manufacturing workers is to have a **better awareness** of the process status in order to have a more conscious decision making process and increase their responsiveness to process breakdown/change. To date in many companies the operators need to actively seek the required information and select the correct information from a large number of data sources to carry out their tasks.

Thus, the main idea of the challenge is to create a “personal” information feed for a specific worker that could support his activity and empower him to become a smart worker with more autonomy and problem-solving capabilities. The solution should provide also the appropriate tools not just “see” the correct data but also to analyse them in the smartest and personalised way. Not only the access to data has to be personal but also the analysis should be developed and selected in order to provide an understanding of the process that will be profitable for the specific worker.

Case vignette 1

Hidria Rotomatika is a Slovenian automotive tier-1 supplier that produces electric stators and rotors for automotive use. We observed operators of the machining departments, who deal with turning and milling machines.

A preliminary analysis of the workers needs has highlighted how some operations could be time-consuming and require the acquisition of paper-based data or knowledge from an experienced colleague. These data must be processed manually in order to obtain a smooth process. Especially machine setup processes and measurements of each part could be very complex and time-consuming. This challenge addresses the core issue of providing natural interfaces that allow workers to interact and access knowledge effectively when performing their regular tasks. The challenge is to enable the workers to utilize big data analytics fuelled by automated electronic measurements to make decisions more effectively when calibrating production equipment. Better access to information and analytics would allow to cut production times while increasing product quality and reducing waste due to making better-informed decisions and detecting patterns and trends in product deviations. For the worker, being able to benefit fully from information generated by machines and previous decisions could reduce frustration and help retaining a productive flow of work.

In the proposed solution, the workers automatically receive all relevant information in a digital format and obtain a fit solution to fix the problem directly at their current work station. Moreover, the operators acquire more autonomy due to the implementation of a trend analysis of the process, which usually means the degradation of some components or machines. In this case the operator becomes a leader of a proactive analysis phase for the machine maintenance that is actually carried out using a traditional reactive approach (repair actions when the process stops due to e.g. a broken part) by the maintenance team. This allows the operator to gain more autonomy and take charge of advanced tasks that are beneficial both for the process (higher availability of the plant) and its satisfaction (higher autonomy and possibility to be the responsible for the process well-being).

4.2 Worker-centric knowledge sharing

Worker-centric knowledge sharing means the utilization of worker-generated content and peer sharing about best practices, problem solving and ideas to fuel organizational learning and even worker-driven innovation (Richter et al., 2013). This includes not only equipping workers with appropriate tools, but also with specific use cases for utilizing these tools (Richter & Riemer, 2013). **Empowering workers to share** their knowledge transparently with others reduces the risk of productivity bottlenecks e.g. through redundant work and improves the pace and depth

of on-the-job learning. At the same time, the worker feels more valued, more socially connected to the work community and better motivated.

Case vignette 2

thyssenkrupp Steel Europe is an international provider of flat steel. We observed the practices of the mobile maintenance team in the areas of air-conditioning technology and electricity.

The occurrence of a fault is reported via phone, email, or fax. Rough information on the type of fault and system is then passed onto the mobile maintenance employee in paper form. Frequently, neither local information of the production site in which the disruption is located nor particular safety instructions are provided. The necessary knowledge is usually acquired through the accompaniment of an experienced colleague or through systematic trial and error, despite a structural knowledge transfer. Since approximately 3,000 different types of systems must be serviced and possibly debugged, employees rarely possess all the relevant information, tools and spare parts to solve a specific problem without a considerable communication effort or multiple journeys. The direct communication in the process of fault elimination is currently supported by mobile phones without access to mobile data. The paper-based, asynchronous information exchange between the employees who are involved in the fault process often leads to delays or redundant work. Furthermore, at the site of the disruption, there is often a lack of knowledge that other employees could deliver. In this case, the opportunities to directly communicate with other colleagues, e.g. to exchange pictures and documents, are missing.

Due to the above-mentioned mobility and the numerous and varied challenges which the maintenance personnel faces, it is important that the workers are provided with the necessary information in a bundled, contextual and mobile way. This will be realized through the implementation of a mobile employee-centred knowledge management system that places the maintenance staff at the centre of attention. The solution can provide necessary information on maintenance in two ways: 1) Context-specific information on all systems can be called up by the employee through a mobile information system. 2) Access to colleagues' practical knowledge can be realized through a chat function with the possibility of exchanging images and videos. These two components support the maintenance employee on his way becoming a smart worker who has access to all necessary knowledge. Through this form of knowledge networking, the communication between colleagues can be increased, practical knowledge exchanged and the process of eliminating faults thereby designed in a more efficient way. Due to the accessibility of relevant information, unnecessary journeys can be avoided and the certainty in the employees' actions increased.

4.3 Self-learning manufacturing workplaces

Self-learning manufacturing workplaces support workers discovering and sharing knowledge during manufacturing, enhancing their competencies and worker satisfaction. However, the manufacturing knowledge and information is currently often scattered across a plethora of information silos without a centralized platform to connect, combine, analyse and organize the information according to the present needs of the shop-floor worker. Mastering the complexity of data and information requires sophisticated semantic and data mining technologies to discover the relationships between different sources (Zhong et al., 2015), allowing intelligent

search and exploration. With the implementation of advanced IT solutions, IoT technologies and sufficient knowledge management procedures, new possibilities for leveraging the manufacturing knowledge arise.

One such concrete advance is the creation of a self-learning manufacturing workplace. Utilizing detailed and consistent data from manufacturing operations, enterprises are able to implement e.g. predictive maintenance and machine-assisted decision making for calibrations that allow reducing unplanned process disruptions and maintaining a smooth workflow (Orio, 2015).

Case vignette 3

Hidria Technology Centre is a Slovenian company, which designs and manufactures a wide spectrum of partially or fully automated assembly lines, ranging from simple conveyer belt designs to fully automated lines. These complex and automated manufacturing lines incorporate lots of fault conditions. The loss in efficiency is due to either time-consuming setup and maintenance activities or lacking supplies. In such cases, the line comes to a halt or produces parts that have not been specified. The increase of operating time and the reduction of maintenance time of the assembly lines are therefore in the focus.

The main worker needs in this case are derived from one of the customer's sites: Hidria Dieselteck plant, which produces glowplugs and pressure sensors. One of the challenges in this case is that operators at the shop floor cannot predict up-coming problems or breakdowns, but instead they work mainly on tasks related to reactive maintenance. Thus, supporting tools for shifting operators' workloads towards more predictive maintenance tasks are desired. Further, operators have to react quickly to resolve problems during manufacturing. The team of operators aim to directly fix small problems like the replacement of defective parts. With larger defaults or more complex problems, the internal maintenance team helps to bring the production up to speed again as quickly as possible. Thus, in this case it is aimed at better supporting the problem-solving activities of the line operators by a new integrated knowledge base of the production line fault analysis. In addition, the solution finding to a problem/breakdown is highly dependent on the experience of the worker, and this knowledge is important to be shared also to less experienced workers for enhancing peer-learning at workplaces. The information and knowledge of manufacturing processes, technologies and solutions is currently scattered across the factory without a centralised platform to store, share and analyse the information according to the present needs of the worker at the shop floor.

A proposed self-learning approach will monitor a combination of human, process and machine parameters, and supports human-machine interaction. The solution offers: 1) a reactive (alarms), 2) predictive (warnings) and 3) proactive (maintenance) decision support to shop floor workers. Reoccurrence of problems will be minimized by storing and sorting the problems systematically and combining them with user generated solutions into the machine book – thereby enabling self-learning workplaces. The solutions to a specific problem can also be rated by the workers. In addition, an employee can generate new solutions in forms of comments, videos or pictures. As a conclusion, self-learning manufacturing workplaces are able to increase the workers' autonomy and competence by providing them the knowledge required for carrying out specific tasks.

4.4 In-situ mobile learning

The increasingly needed flexibility of workers leads them to perform a wider range of tasks and share more responsibilities in manufacturing (Appelbaum 2013). This causes the pervasive need of overall on-the-job knowledge, available at the right time in the right place. Furthermore, knowledge is subject to continuous change as work practices evolve and requirements change. So far, declarative and often abstract generic knowledge is acquired “off-the-job”, and it appears that this gap can be bridged by mobile learning in the right context (Aehnelt & Wegner, 2015; Frohberg et al., 2009; Ullrich, 2016). Workers need context-aware learning in real-life situations for continued education and training.

Since in-situ learning is relatively new to manufacturing environments, the challenge includes finding the optimal way to utilize contextual and real-time machine-generated data, and to design and deliver the learning service so that it is effective, efficient and widely accepted.

Case vignette 4

Schaeffler is a large German automotive supplier. The studied plant recently changed the former functional shop floor organization towards a new value stream design.

Along with these organizational changes came changes to the role of the individual worker. Formally deeply specialized personnel now works in diversified areas requiring a variety of skills and knowledge. However, expert knowledge is still needed to solve tough problems. Currently there are three steps for competence development within the company: formal trainings for learning factual knowledge, mentoring for the transfer of expert knowledge and the learning directly on the shop floor within real working contexts right at the machines. In these settings, several problems surface: (1) the knowledge transferred in formal trainings is not directly related to specific workplace requirements. (2) Mentoring defines the learning content and its recipients only through specific circumstances. (3) Learning directly on the machine is difficult as the complexity of the problem often requires an expert onsite which induces a resource problem.

As a solution, a mobile learning approach enables the company to detach knowledge transfer from formal contexts and enables the learner to consume the knowledge when needed. Four core components allow individual, context specific learning and therefore facilitate a sustainable learning arrangement. 1) The learning system includes a sensory interface to the workplace, sensing the machine state as well as the operator. 2) An automatic evaluation of the incoming sensory data provides context- and situation-sensitive problem-solving and learning content. In case of an unknown or currently unresolvable problem, expert assistance is necessary. 3) In such cases the expert would be included into the situation virtually first using audio/video tele cooperation. 4) With the usage of wearable Augmented Reality (AR) devices, such as data glasses, the learning context becomes completely immersed into the work place and the current work situation. As the worker has both hands free, true parallel working and learning is possible. With the introduction of appropriate learning systems, the transaction costs for identifying and consuming necessary information can be reduced. Also, the breakthroughs in mobile device technologies over the past years now allow the design of innovative learning arrangements whereby the boundaries between working and learning will disappear in the future.

5 Discussion

In the last years technical infrastructures have become more and more sophisticated, with large bandwidth networks, affordable software solutions and large storing capacities. Notwithstanding, as we have shown in this paper, a number of sociotechnical trends lead manufacturing companies to change the way they work.

One of these changes includes designing people-centred workspaces that pay more attention to their employees and put them into the centre of their efforts (Campatelli et al., 2016; Steinhüser et al., 2017). Creating an environment that contributes to more efficiency and increasing workplace satisfaction requires more than just implementing appropriate technical solutions. As technology matures, the focus of IT development can shift from a largely technical perspective to a more holistic sociotechnical perspective. Rather than focusing on centralized computer systems and treating the worker as an entity, not yet replaced by machines, the humanistic view focuses on human-human interactions where IT serve as tools to deliver support for specific tasks (Nurminen, 1987). When we acknowledge that the human worker keeps a preferred role in future manufacturing systems through the ever-rising demand in complexity, knowledge work and decision making, the humanistic perspective might be the only sustainable point of view to take. Taking this view, it also seems easier to design for basic human needs as autonomy, relatedness and competence (Gagné & Deci, 2005; Spreitzer, 1997) as well as variety (Turner & Lawrence, 1965) in the first place, as these can be formulated as core objectives enabling a humanistic design approach.

Advances in technology and organizational themes as well as changes in the society are important input variables that stimulate the creative process of designing future work environments. Although called “digital challenges” they have one common theme: Keeping the worker “in the loop” with appropriate information. Moreover, the digital challenges aim to extend the natural sensory reach and information processing capabilities of an individual human worker (self-learning manufacturing workplaces), the field of interaction, e.g. vision, touch or hearing (digitally augmented human work) and further aim to strengthen knowledge absorption capabilities of individuals (in-situ mobile learning) and knowledge distribution within communities (worker-centric knowledge sharing).

6 Conclusion

We started this paper with an overview of emerging sociotechnical trends in manufacturing that coalesce to establish new ways of work in smart factories. Technological advancements in terms of IoT, Big Data and others drive organisational change in a manner not previously seen. Organisations must simultaneously incorporate and leverage the increasing shifts in technologies whilst maintaining a corporate culture that facilitates the most efficient and effective work force. Consequently, employees on the shop floor are expected to adjust their work practices to take into account the changing technologies and increasing complexity.

Drawing on the detailed insights from six manufacturing companies that we gathered as part of a European project aiming to create attractive and intelligent work places in a factory of the future, we demonstrate how the manufacturing industry can leverage challenges they are experiencing. With this conceptualisation of the current situation as “digital challenges” for

manufacturing companies, we contribute to a better theoretical understanding of the changing nature of IT on the Shop Floor.

The four illustrated digital challenges span a wide range and are capable of supporting different facets of the knowledge practices in manufacturing companies. Taking into account different knowledge management facets helps to better understand and meet the needs and requirements as expressed by prospective users moving them in the focus of the implementation efforts.

We have observed that workers expect new digital solutions to draw on what they already are familiar with from their private lives, e.g. designing, commenting, searching or networking functionalities in the style of well-known internet platforms. In this context, ICT seems to play more and more the role of a hygiene factor that supports the workers in an “invisible” way. This implies that the pure existence of a new solution is not in itself able to give increased satisfaction or lead to higher motivation, however dissatisfaction often results from its absence or inadequate design. This calls for more research that contributes to creating worker-centric factory solutions of the future.

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